Triadic Resonance in GUFT: Linking Space, Color, and Charge

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Abstract

We advance the hypothesis that the observed "three-ness" of our universe—three spatial dimensions, the three color charges of QCD, and the quantization of quark electric charge in units of 1/3 of the electron charge—arises from a single *triadic resonance mode* of the Dark Energy Quantum Field (DEQF). Within the Grand Unified Field Theory of Asymmetry (GUFT), spacetime geometry, gauge symmetries, and conservation laws all emerge from phase patterns of the DEQF. We argue that the same cubic invariants that stabilize three-dimensional external geometry also stabilize $SU(3)$ as the internal color group, with anomaly cancellation providing the resonance balance that enforces quark charges on a 1/3 lattice. This unifies spatial dimensionality, internal symmetry, and charge quantization as parallel expressions of one resonance principle, extending earlier GUFT results on c, Λ, the arrow of time, and conservation. We provide explicit toy-model minimization showing the energetic preference for $N_c = 3$, quantitative NDA estimates for curvature-suppressed corrections, and a concrete observational roadmap.

1 Introduction: The Problem of Three

Physics presents a recurring pattern of threes. The universe has three extended spatial dimensions; quarks carry three colors; and their electric charges come in multiples of one third of the electron's. In the Standard Model these facts are independent: space is a 3-manifold, QCD is an $SU(3)$ gauge theory, and fractional charges are chosen to cancel anomalies. In GUFT, where spacetime and gauge symmetries are emergent phases of the DEQF, such coincidences should admit a common origin. We call that origin *Triadic Resonance*.

Scope. This paper formalizes the triadic mechanism and connects it to prior GUFT results, then derives predictions, bounds, and falsifiers. Throughout we work at the level of an effective description; microscopic UV details are deferred to future work.

2 Review of Prior GUFT Results

2.1 GUFT Asymmetry

Spacetime and gravity are emergent phases of the DEQF, with Standard Model fields arising as topological excitations. Anomaly cancellation is reframed as a geometric resonance condition $\sum_i Q_i^3 = 0$ [1].

2.2 Deriving c

The speed of light emerges as the ratio of temporal and spatial expansion coefficients, both projections of DEQF pressure [2].

2.3 DEQF Static Pressure

The invariant pressure P_0 explains c, Λ, the arrow of time, entropy growth, and matter–antimatter asymmetry [3].

2.4 Conservation and Coherence

The Trimm Conservation Axiom ties conservation to the divergence-free condition on the pressure coherence tensor $\kappa_{\mu\nu}$, with collapse described as constrained coherence routing [4].

3 Triadic Invariants in DEQF Condensation

The DEQF supports invariants of the form: (i) external (spatial): the Levi-Civita tensor ϵ^{ijk}, nontrivial only in 3D; and (ii) internal (color): the symmetric $SU(3)$ tensor d^{abc}, nontrivial only for $N_c \geq 3$.

3.1 Physical nature of DEQF currents

Definitions. The DEQF currents J_μ^a admit two complementary definitions: (i) *Noether:* for Ψ transforming as $\delta\Psi = i\alpha^a T^a \Psi$, the conserved current $J_\mu^a = i\Psi^\dagger T^a D_\mu \Psi + \text{h.c.}$; (ii) *Geometric:* writing $\Psi = \rho U(x)$ with $U \in G$ gives $A_\mu^a \simeq -i\,\mathrm{Tr}(T^a U^{-1}\partial_\mu U)$ and J_μ^a as the flow of internal orientation.

Physical intuition. J_μ^a is a *supercurrent of internal phase.* Gradients of $U(x)$ generate persistent currents in internal space, analogous to mass supercurrents in superfluids or spin supercurrents in spinor condensates. Topological defects are phase-slip loci; their endpoints/junctions act as sources/sinks of J_μ^a. Operationally, J_μ^a couples to emergent gauge fields, biases color alignment in matter, and produces small in-medium response shifts.

Operational cues. One expects (i) tiny density-dependent shifts in effective gauge couplings inside matter; (ii) defect-mediated hysteresis in color-alignment energetics under strong compression; (iii) curvature-linked modulation of in-medium spectral features (quantified in Sec. 8).

3.2 Triadic locking term

The lowest-order mixed invariant is

$$\mathcal{L}_{\rm mix} = -\lambda\, \epsilon^{ijk} d^{abc} J_i^a J_j^b J_k^c, \qquad \lambda > 0. \tag{1}$$

It is nonzero only if both $d = 3$ and $N_c \geq 3$, locking external and internal triads and lowering free energy in the $(3, 3)$ phase.

3.3 Energetic selection: toy Landau calculation

We construct a Landau functional for Φ_i^a (spatial triad $i = 1, 2, 3$, color adjoint $a = 1, \ldots, N_c^2 - 1$):

$$\mathcal{F} = \tfrac{m^2}{2}\Phi^2 + \tfrac{u}{4}(\Phi^2)^2 + \tfrac{v}{4}\sum_{i\neq j}(\Phi_i\cdot\Phi_j)^2 - \lambda\, \epsilon^{ijk} d^{abc}\Phi_i^a\Phi_j^b\Phi_k^c + \alpha\,(N_c^2-1)^p\,\rho^4, \tag{2}$$

with $\Phi^2 \equiv \sum_i \Phi_i^a\Phi_i^a$, $p > 1$ the coherence-strain exponent, and ρ a typical amplitude. Under the triad ansatz $\Phi_i^a = \rho\, n_i^a$ with $\sum_a n_i^a n_j^a = \delta_{ij}$, the cubic invariant is bounded by

$$C(N_c) \equiv \max_{n_i} d^{abc} n_1^a n_2^b n_3^c = \sqrt{d^{abc}d^{abc}} = \sqrt{\frac{(N_c^2-1)(N_c^2-4)}{N_c}}. \tag{3}$$

Collect the N_c-dependent quartic into $b(N_c) = u'(N_c^2-1) + 4\alpha(N_c^2-1)^p$ with $u' > 0$. Then

$$F(\rho; N_c) = \tfrac{a}{2}\rho^2 - \lambda\, C(N_c)\,\rho^3 + \tfrac{b(N_c)}{4}\rho^4, \qquad a \equiv m^2 + 2v. \tag{4}$$

The nontrivial extremum satisfies $a - 3\lambda C\rho + b\rho^2 = 0$. In the condensed regime ($a \approx 0^+$) one obtains

$$\rho_* \;=\; \frac{3\lambda C(N_c)}{b(N_c)}, \qquad F_{\rm min}(N_c) \;=\; -\frac{27}{4}\,\frac{\lambda^4\, C(N_c)^4}{b(N_c)^3}. \tag{5}$$

Thus the figure of merit

$$\mathfrak{F}(N_c) \equiv \frac{C(N_c)^4}{b(N_c)^3} = \frac{\big[(N_c^2-1)(N_c^2-4)/N_c\big]^2}{\big[u'(N_c^2-1) + 4\alpha(N_c^2-1)^p\big]^3} \tag{6}$$

is maximized at the smallest admissible N_c for any $p > 1$ once α exceeds modest thresholds. A closed-form bound against $N > 3$ is

$$\alpha \geq \frac{u'\big[C(N)^{4/3}(3^2-1) - C(3)^{4/3}(N^2-1)\big]}{4\big[C(3)^{4/3}(N^2-1)^p - C(N)^{4/3}(3^2-1)^p\big]} \tag{7}$$

(with $C(N)^{4/3} = \big((N^2-1)(N^2-4)/N\big)^{2/3}$). Numerically, for $u' = 1$, $p = 1.5$: $\alpha_{\rm min}(4) \approx 0.106$, $\alpha_{\rm min}(5) \approx 0.056$, $\alpha_{\rm min}(6) \approx 0.038$.

4 Anomaly Cancellation as Resonance Balance

Anomaly cancellation requires $\sum_i Q_i^3 = 0$, interpreted in GUFT as a resonance balance on the DEQF defect network.

4.1 Cohomological form of the resonance constraint

The abelian gauge anomaly is encoded by the 6-form polynomial

$$\mathcal{I}_6 = \frac{1}{6}\Big(\sum_f q_f^3\Big)\Big(\frac{F}{2\pi}\Big)^3 \in H^6(BU(1),\mathbb{Z}). \tag{8}$$

In the triadic phase a bulk Chern–Simons term at level k produces $\delta S_{\mathrm{CS}} = -(24\pi^2)^{-1}\int_{\partial\mathcal{M}_5} \alpha\, F\wedge F\wedge F$. Gauge invariance on closed defect graphs requires $k = \sum_f q_f^3$; compactness enforces $k = 0$, hence $\sum_f q_f^3 = 0$.

5 The Triadic Resonance Hypothesis

Hypothesis: The DEQF condensate minimizes free energy through triadic invariants that are simultaneously external (ϵ^{ijk}), internal (d^{abc}), and anomaly-balanced ($\sum Q^3 = 0$). This locks spatial dimensionality to $d = 3$, color multiplicity to $N_c = 3$, and electric charges to the 1/3 lattice.

6 Predictions, Falsifiers, and Decision Tree

- No stable universes with $d \neq 3$ and $N_c = 3$.
- No stable universes with $N_c \neq 3$ and $d = 3$.
- Charge quantization restricted to integers and thirds; no exotic 1/5 or irrational quanta.
- Curvature-dependent renormalization of SM couplings with Ricci scaling (density dependence).

Decision tree. (i) If line-ratio bounds in high-$\mathcal{R}$ photospheres improve, update $M_*/\sqrt{\zeta_i}$; (ii) if laboratory density toggles improve beyond 10^{-17}, compare with neutron-star bounds; (iii) if any $d \neq 3/N_c \neq 3$ effective phase is realized in an analog simulator without catastrophic instabilities, TRH is falsified.

7 Quantitative estimates and ζ_i ranges

Corrections scale as

$$\frac{\Delta\alpha_i}{\alpha_i} \approx \zeta_i \frac{\mathcal{R}}{M_*^2}. \tag{9}$$

How to compute ζ_i. (i) *Microscopic matching:* introduce a gapped mode T with $\mathcal{L} \supset \frac{1}{2}(\partial T)^2 - \frac{1}{2}m_T^2 T^2 + g_T T\, \mathcal{O}_{\rm triad} + \sum_i \kappa_i T\, \frac{1}{4}F^{(i)}_{\mu\nu}F^{(i)\mu\nu}$; integrating out T gives $\zeta_i \simeq \beta(g_T\kappa_i/m_T^2)M_*^2$ when $\langle \mathcal{O}_{\rm triad}\rangle = \beta\,\mathcal{R}\,M_*^2$. (ii) *Kubo:* $\zeta_i/M_*^2 = \lim_{\omega\to 0}\frac{1}{\omega}\,\Im\!\int \mathrm{d}^4x\, e^{i\omega t}\,\langle[\mathcal{O}_{\rm triad}(x), \frac{1}{4}F^{(i)2}(0)]\rangle$. (iii) *NDA:* $\zeta_i \sim c_i\lambda^2/(16\pi^2)$ with $c_i = \mathcal{O}(1)$.

NDA ranges. Taking $\lambda \in [0.4, 2]$ gives $\zeta_i \in [10^{-3},\, 2.5\times 10^{-2}]$. In neutron-star cores with $\mathcal{R} \sim 6\times 10^4\,\mathrm{eV}^2$ this implies $\Delta\alpha/\alpha \sim (10^{-23}\text{–}10^{-21}) \times (\mathrm{TeV}^2/M_*^2)$.

8 Observability and bounds

Laboratory null (density toggle). In vacuum exteriors $R = 0$, so no orbital/altitude signal is expected; only insertion into matter changes $\mathcal{R} \propto \rho$. Comparing identical frequency standards in UHV versus a high-density solid provides a null bound, though present sensitivities ($\sim 10^{-17}$) are far above the estimates here.

Astrophysical line-ratio test. Accreting neutron stars furnish the largest accessible $\mathcal{R}$ at a visible photosphere. Using line pairs with different α-sensitivities (e.g., Fe XXV He-like triplet at $\sim 6.70\,\mathrm{keV}$ and Fe XXVI Lyα at $\sim 6.97\,\mathrm{keV}$; Ni features at $7.8\,\mathrm{keV}$ to $8.1\,\mathrm{keV}$) cancels gravitational redshift in ratios. Fitting simultaneous pairs across bursts yields a bound B on $|\Delta\alpha/\alpha|$ at $\mathcal{R}_{\rm phot}$, implying $M_* > \sqrt{\zeta_i\,\mathcal{R}_{\rm phot}/B}$. Current microcalorimeters (Chandra/HETG, XRISM/Resolve) provide loose bounds; Athena/XIFU will sharpen them decisively.

9 Simulation and Analog Roadmap

Numerical. Minimize the Landau functional (Sec. 3.3) on a lattice for $N_c = 2, 3, 4, 5$; map $\mathfrak{F}(N_c)$ as a function of (p, α, λ); verify the $N_c = 3$ maximum and extract threshold surfaces.

Analog. Engineer a spinor BEC with a cubic spin-locking term (optical dressing) to realize an external-internal triad; test whether the smallest spin supporting the cubic invariant is dynamically selected.

10 Open Questions and Future Directions

10.1 Microphysics of the DEQF condensate

The placeholder field T used to parametrize triadic response should be derived from the condensate itself. Two concrete possibilities deserve dedicated treatment: (i) an *amplitude (Higgs-like) mode* h of the triadic order parameter Φ_i^a (with $T \equiv h$), and (ii) a *phase (Josephson-like) mode* ϑ associated with inter-sector phase locking of DEQF to emergent gauge frames. A third, topological option is a Kalb–Ramond 2-form $B_{\mu\nu}$ whose 3-form field

strength $H = \mathrm{d}B$ counts defect density. A minimal effective sector capturing these cases is

$$\mathcal{L}_T = \tfrac{1}{2}(\partial T)^2 - \tfrac{1}{2}m_T^2 T^2 + \beta_T\, T\, \mathcal{R} + \sum_i \kappa_i\, T\, \tfrac{1}{4}F^{(i)}_{\mu\nu}F^{(i)\mu\nu} + \gamma_T\, T\, \epsilon^{ijk} d^{abc} J_i^a J_j^b J_k^c + \cdots\,, \quad (10)$$

with dispersion $\omega^2 = m_T^2 + v_T^2 k^2$. A microscopic derivation should start from a concrete $V[\Phi]$, expand about the triadic vacuum to identify (h, ϑ), and integrate out heavy modes to match $(m_T, \beta_T, \kappa_i, \gamma_T)$—thereby computing ζ_i without relying on NDA.

10.2 How triadic resonance might relate to three fermion generations

Triadic resonance explains $d = 3$, $N_c = 3$, and the 1/3 charge lattice. Whether it also explains the *three fermion generations* remains open. Two nonexclusive routes:

1. **Defect-multiplicity route:** three inequivalent triadic junction classes (distinguished by DEQF winding data) localize three families as zero modes with hierarchical overlaps.

2. **Residual discrete-symmetry route:** a discrete remnant of the triadic phase (e.g. S_3 or A_4 acting on a flavor bundle) organizes chiral matter into a three-dimensional irrep.

In both cases one expects Yukawa textures

$$Y_{ij} \;\sim\; \int \mathrm{d}^3x\; \psi_L^{(i)}(x)\, \Phi_H(x)\, \psi_R^{(j)}(x) \;\propto\; e^{-S_{ij}[\text{triad geometry}]}, \quad (11)$$

linking hierarchies and mixings to triad geometry. Making this concrete requires specifying defect-graph statistics and the residual flavor symmetry of the DEQF phase.

10.3 Could triadic resonance seed other "3's"?

Beyond color and space, the triadic phase may underpin additional three-fold structures: (i) *baryon triality* ($\mathbb{Z}_3$) as a topological charge of defect junctions (motivating selection rules against certain B-violating channels); (ii) *lepton-flavor triplicity* if a flavor bundle locks to the triad; and (iii) *Y-shaped confinement geometry* as the energetically preferred baryonic string configuration. Each candidate yields qualitative signatures (selection rules, spectrum patterns) that can be tested against data or lattice QCD.

Programmatic next steps. (1) Derive T from a specified $V[\Phi]$ and compute $(m_T, \beta_T, \kappa_i, \gamma_T)$; (2) build a concrete flavor-bundle model (choose S_3/A_4 remnant, write allowed operators, fit CKM/PMNS); (3) simulate the Landau functional with defect networks to test generation localization and baryon triality; (4) propagate the microphysical matches into sharpened predictions for ζ_i and neutron-star line-ratio bounds.

11 Conclusion

The recurrence of "three"—3D space, $SU(3)$ color, and 1/3 charges—is explained in GUFT as a single triadic resonance of the DEQF. This extends prior GUFT results by tying dimensionality, internal symmetry, and charge quantization to a common invariant structure, while offering concrete bounds and a simulation/observational roadmap.

Appendix A: Detailed derivation of the toy-model minimum

We minimize $F(\rho) = \frac{a}{2}\rho^2 - \lambda C\rho^3 + \frac{b}{4}\rho^4$. The stationary condition $\partial_\rho F = 0$ gives $a - 3\lambda C\rho + b\rho^2 = 0$ with solutions $\rho_\pm = \frac{3\lambda C \pm \sqrt{9\lambda^2 C^2 - 4ab}}{2b}$. In the condensed regime ($a \to 0^+$), $\rho_* = 3\lambda C/b$ and $F_{\min} = -\frac{27}{4}\lambda^4 C^4/b^3$. Including small $a > 0$ adds corrections of order $\mathcal{O}(a\lambda^2 C^2/b^2)$ and does not change N_c selection.

Appendix B: Computing ζ_i

Microscopic matching. Introduce a gapped scalar T with $\mathcal{L} \supset \frac{1}{2}(\partial T)^2 - \frac{1}{2}m_T^2 T^2 + g_T T\, \mathcal{O}_{\text{triad}} + \sum_i \kappa_i T\, \frac{1}{4}F^{(i)}_{\mu\nu}F^{(i)\mu\nu}$. Integrating out T generates $\Delta\mathcal{L}_{\text{eff}} = \sum_i (g_T\kappa_i/m_T^2)\, \mathcal{O}_{\text{triad}}\, \frac{1}{4}F^{(i)}_{\mu\nu}F^{(i)\mu\nu}$. In a slowly varying background $\langle \mathcal{O}_{\text{triad}} \rangle = \beta\, \mathcal{R}\, M_*^2$, identifying $\zeta_i \simeq \beta(g_T\kappa_i/m_T^2)M_*^2$.

Linear response (Kubo). $\zeta_i/M_*^2 = \lim_{\omega\to 0} \frac{1}{\omega}\, \Im \int \mathrm{d}^4x\, e^{i\omega t}\, \langle [\mathcal{O}_{\text{triad}}(x), \frac{1}{4}F^{(i)2}(0)] \rangle$.

NDA. $\zeta_i \sim c_i\lambda^2/(16\pi^2)$ with $c_i \sim \mathcal{O}(1)$.

Appendix C: Spectral lines and sensitivities

Hydrogenic-like transitions scale as $E \propto \alpha^2$ to leading order; fine-structure splittings have $\delta E/E \approx K\, \delta\alpha/\alpha$ with $K \sim 2$ for Lyα, and different K for He-like triplets. A Many-Multiplet-style ratio of Fe XXV (He-like) to Fe XXVI (H-like) lines isolates $\delta\alpha/\alpha$ while dividing out gravitational redshift. For Athena/XIFU (few-eV resolution at $\sim 7\,\text{keV}$), optimistic stacked-burst analyses may reach $B \sim 10^{-4}$ for line ratios, constraining $M_*/\sqrt{\zeta_i}$ at the photospheric $\mathcal{R}$.

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